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Sustainable experimentation in Chemistry Teaching: Batch Adsorption Technique with activated carbon from the endocarp of coconut in water treatment

Experimentação sustentável no Ensino de Química: Técnica de Adsorção em Batelada com o carvão ativado do endocarpo do coco-da-baía no tratamento da água

Experimentación sostenible en la enseñanza de Química: Técnica de Adsorción Lote con carbón activado de endocarpo de coco-da-baía en el tratamiento de aguas

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Abstract

Chemistry is generally viewed in a repulsive way by high school students. This problematic condition is the result of the various impasses generated by traditionalist methods that are being applied in schools, such as the lack of contextualization in the teaching of Natural Sciences. Therefore, this study aimed to develop experimental classes contextualized to the socio-scientific dimensions of Chemistry; as well as based on Environmental Education (EA) in a class of the 4th year of the Technical Course Integrated to High School of Controle Ambiental do Instituto Federal de Educação, Ciência e Tecnologia da Paraíba - IFPB, João Pessoa *campus*. In this sense, by mediation of a mixed approach (qualitative and quantitative), the research group presented to the students a low-cost process for improving water quality via Batch Adsorption with activated carbon from the endocarp of the coconut (biodegradable adsorbent material for the treatment of hard water). The activity was divided into three parts: i) Application of the Virtual Survey Questionnaire (VSQ); ii) Conducting experimental classes; iii) Application of the Final Virtual Questionnaire (FVQ). In this process, the students presented satisfactory considerations regarding the pedagogical intervention, showing that this practice was important for technical and citizen training. Thus, the research in question aims to enable the pedagogical community to acquire new skills and abilities regarding the work of the implementation of EE, involving Green Chemistry (GC) and the Sustainable Development Goals (SDGs), in the school menu.

Keywords: Experimentation; Chemistry teaching; Sustainable development; Green chemistry; Water treatment.

Resumo

A Química é geralmente encarada de forma repulsiva pelos estudantes do Ensino Médio. Essa condição problemática é resultante dos diversos impasses gerados pelos métodos tradicionalistas que estão sendo aplicados nas escolas, tais como a carência da contextualização no ensino das Ciências da Natureza. Diante disso, o presente trabalho objetivou desenvolver aulas experimentais contextualizadas às dimensões sociocientíficas da Química; bem como fundamentadas

na Educação Ambiental (EA) em uma turma do 4º ano do Curso Técnico Integrado ao Ensino Médio de Controle Ambiental do Instituto Federal de Educação, Ciência e Tecnologia da Paraíba - IFPB, *campus* João Pessoa. Nesse sentido, por mediação de uma abordagem mista (qualitativa e quantitativa), o grupo de pesquisa apresentou para os estudantes um processo de baixo custo para a melhoria da qualidade da água via Adsorção em Batelada com o carvão ativado do endocarpo do coco-da-baía (material adsorvente biodegradável para o tratamento da água dura). A atividade foi dividida em três partes: i) Aplicação do Questionário Virtual de Sondagem (QVS); ii) Realização das aulas experimentais; iii) Aplicação do Questionário Virtual Final (QVF). Nesse processo, os discentes apresentaram considerações satisfatórias quanto à intervenção pedagógica, evidenciando que essa prática foi importante para a formação técnica e cidadã. Assim, a pesquisa em tela almeja possibilitar à comunidade pedagógica a aquisição de novas competências e habilidades no que tange o trabalho da implementação da EA, envolvendo pautas da Química Verde (QV) e dos Objetivos de Desenvolvimento Sustentável (ODS), na ementa escolar.
Palavras-chave: Experimentação; Ensino de química; Desenvolvimento sustentável; Química verde; Tratamento de água.

Resumen
La química generalmente es vista con repulsión por los estudiantes de secundaria. Esta condición problemática es el resultado de los diversos impasses generados por los métodos tradicionalistas que se están aplicando en las escuelas, como la falta de contextualización en la enseñanza de las Ciencias Naturales. Ante esto, el presente trabajo tuvo como objetivo desarrollar clases experimentales contextualizadas a las dimensiones sociocientíficas de la Química; así como con base en la Educación Ambiental (EA) en una clase de 4º año del Curso Técnico Integrado a la Escuela Superior de Control Ambiental del Instituto Federal de Educación, Ciencia y Tecnología de Paraíba - IFPB, campus João Pessoa. En este sentido, a través de un enfoque mixto (cualitativo y cuantitativo), el grupo de investigación presentó a los estudiantes un proceso de bajo costo para mejorar la calidad del agua mediante Adsorción Batch con carbón activado de endocarpio de coco bahía (material adsorbente biodegradable para el tratamiento de aguas duras). agua). La actividad se dividió en tres partes: i) Aplicación del Cuestionario de Encuesta Virtual (QVS); ii) Realización de clases experimentales; iii) Aplicación del Cuestionario Final Virtual (QVF). En ese proceso, los estudiantes presentaron consideraciones satisfactorias sobre la intervención pedagógica, demostrando que esta práctica fue importante para la formación técnica y ciudadana. Por lo tanto, la investigación de pantalla tiene como objetivo permitir que la comunidad pedagógica adquiera nuevas habilidades y destrezas en relación con el trabajo de implementación de EE, involucrando las directrices de Química Verde (QV) y Objetivos de Desarrollo Sostenible (ODS) en el currículo escolar.
Palabras clave: Experimentación; Enseñanza de la química; Desarrollo sostenible; Química verde; Tratamiento de aguas.

1. Introduction

Chemistry Teaching is generally interpreted negatively by high school students. This perspective is the result of the various impasses resulting from traditionalist methods that are applied in schools. The use of archaic and inadequate approaches and methodologies, such as those that do not use the contextualization between scientific content and its applications in society, are examples of factors that drive ineffectiveness in learning Chemistry (Lima et al., 2022).

The contextualization process in teaching builds a mechanism of mediation between students and the contents addressed in the classroom, motivating them to identify and relate their school knowledge to their experiences (Corrêa, 2022). However, this is still a didactic tool little explored by many teachers from different areas of science. In this opportunity, for the effective application of contextualization in Chemistry Teaching, it is necessary to establish a direct link between this methodology and the development of experimental activities, since through practical actions the students' understanding becomes genuine (Mello, et al., 2018).

Santos and Menezes (2020) corroborate this information, stating that the teaching of chemical content must adapt to the student reality. As a result, practical classes and their social, cultural and economic dimensions can help in the teaching and learning process, promoting a citizen formation for students (Orphan & Alvim, 2022; Da Silva Júnior, et al., 2022). Tangent to this, the focus on socio-scientific themes, such as Green Chemistry (GC) and the Sustainable Development Goals (SDGs), from the pedagogical perspective, can be viewed as an effective strategy, since it allows socio-environmental debates to be addressed in the school chemistry curriculum (Ventapane & Santos, 2020; Tavares et al., 2022a; Da Silva Júnior et al., 2022).

In general, GC is "a multidisciplinary area that creates, develops and applies chemical products and processes that aim to reduce or eliminate the use and generation of substances harmful to the environment and man" (Da Silva Júnior, et al., 2022, p. 1010). In this same sustainable perspective of GC, the 17 SDGs, in a more comprehensive way, aim, through several goals, to enable people to achieve quality of life (IYBSSD, 2022). Thus, both areas mentioned relate and complement each other directly.

In this bias, the expansion of experiments that are based on the principles of GC and the goals of the SDGs needs to be explored by chemistry teachers. One suggestion for such a demand would be the thematic contextualization of SDG 6 (drinking water and sanitation). Thus, low-cost experimentation with natural resources, such as water treatment by Batch Adsorption, are potential didactic alternatives for Chemistry.

The Batch Adsorption system allows to evaluate the amount adsorbed from simple models and used in numerous applications (Santos, 2021), being also a technique that evaluates the adsorptive capacity of possible adsorbent substrates used in water treatment. The main variables involved in batch processes are temperature, mass of adsorbent substrates, concentration of adsorbate (adsorbed material) and agitation speed (Nascimento et al., 2014). Other variables can be taken into account, but most of the time they are not relevant.

Adsorbent substrates are natural or synthetic materials, whose access to the internal surfaces of their pores depends on a natural selection that occurs between the adsorbent and the adsorbate. From an economic and sustainable point of view, an adsorbent must have certain characteristics, and the ones that stand out most as important are: high surface area, selectivity, efficiency, mechanical resistance, lowest possible load loss, chemical inertia and low cost (Curbelo, 2002).

Therefore, with a suggestion to mitigate the problems of water demand, this study aimed to develop contextualized experimental classes with a low-cost process to improve water quality. More specifically, Batch Adsorption was addressed with activated carbon from the coconut endocarp, a biodegradable adsorbent material for the treatment of hard water. This intervention is justified as an economic and efficient proposal for the Teaching of Chemistry, as it unites the paradigms of the discipline with the empirical knowledge of the students, facilitating the assimilation and cognition of the contents for them.

2. Methodology

The present pedagogical intervention had an experimental approach. This didactic treatment was chosen due to its problematizing character, being characterized as an efficient strategy for learning Chemistry and other areas of science, especially for high school students (Souza & Muniz, 2020).

For the analysis of the results obtained, a mixed research methodology (quantitative and qualitative) was used; based on pragmatism, due to the multiplicity of perspectives, theoretical assumptions and collection techniques. Thus, we sought to establish a mutual relationship between these scientific approaches, contributing to the acquisition of knowledge for both the respondents and the researchers (Leite et al., 2021).

In this scenario, the research group was composed of three (3) professors from the Federal Institute of Education, Science and Technology of Paraíba – IFPB, from the João Pessoa, Sousa and Cabedelo *campuses*. In addition, there was also the participation of two (2) students of the Chemistry Degree course at IFPB, João Pessoa *campus*. This team developed the action in a class of the 4th (fourth) year of said institution, which attended the Technical High School Integrated in Environmental Control, composed of 27 (twenty-seven) students. The methodological process for the application of the research was divided into 3 (three) moments, as shown in Table 1.

Table 1 - Methodological Procedure.

MOMENTS	SHARES	DESCRIPTION
1st	Application of the Virtual Survey Questionnaire (VSQ)	Virtual material developed at *Google Forms*, with the objective of analyzing the students' previous knowledge regarding GC and SDG contents 6.
2nd	Experimental classes	● **Batch adsorption process through activated carbon from the endocarp of the coconut:** The first experimental class was held in order to contextualize the socio-scientific concepts of Chemistry, through a socio-environmental problem: Water treatment; ● **Determination of Hardness:** The second experimental class took place with the purpose of gathering quantitative data regarding the functionality of the Batch Adsorption practice. In this context, a mathematical calculation was performed to verify the hardness of the water after the treatment carried out at the Physicochemical Laboratory of IFPB.
3rd	Application of the Final Virtual Questionnaire (FVQ)	With the completion of the experimental classes, the FVQ was applied, which served to qualitatively analyze the students' understanding of the pedagogical intervention.

Source: Own source (2022).

These steps were developed by the research group that attended online and face-to-face meetings. The participation of the chemistry professor was essential for the progress of these actions described in Table 1. For example, it was possible the access to the Physical-Chemistry laboratory at the IFPB.

It is worth noting that due to the involvement of people in the progress of the project, an evaluation was necessary for the approval of the Research Ethics Committee (REC) of IFPB. This approval was established by the Certificate of Presentation of Ethical Assessment (CAEE): 57464422.1.0000.5185, as regulated by Resolution No. 466 of December 12, 2012, of the National Health Council (CNS) (Brazil, 2012). In this way, students played an active and assured participation throughout the research.

3. Results and Discussion

As indicated by the methodological path of the research, the first moment was the application of the VSQ with the class. This digital material had the function of gathering and verifying the students' previous understandings regarding GC, SDG 6, and the relations of such themes with their daily lives. In the VSQ there were 2 (two) questions: I. *Do you know the Sustainable Development Goal 6?*; II. *Do you know Green and Sustainable Chemistry?* It is important to inform that the sending of the evaluation instruments to the students took place through a *WhatsApp group.*

As already mentioned in this text, the class in which the research took place is composed of students completing an Environmental Control course, so it is possible to predict that these students already had some relationship with the socio-scientific themes of Chemistry. However, the GC data indicated a contrary situation, since 77.3% did not know SDG 6, and 70.2% also did not know GC, or had only heard about it superficially.

The aforementioned data show a considerable distance from students with the socio-environmental themes explored in this scientific study. This condition brings a problematic perspective to this educational scenario, as it exposes how the lack of contextualization between Environmental Education (EE) and Nature Sciences is still a barrier in the teaching and learning process. Farias (2021) reaffirms this understanding when he informs that "the traditional educational space generally cannot address the environmental theme satisfactorily" (p. 21). Similarly, Tavares et al. (2022b) evidenced the low frequency of these topics in Basic Education classes.

The essential documents of the teaching profession, as in the example of the Complementary Educational Guidelines to the National Curriculum Parameters (PCN+), bring the idea of the transversality of EE in the various areas of science (Pereira, et al., 2020; Brasil, 2002), enabling means of work with focus on the contents of Biology, Geography, Chemistry, among other disciplines (Silva Neto & Araújo, 2021). However, the low exploration of EE as a means of substantiating the contents discussed in the classroom, ends up removing the students' cognition of the applications of these concepts in reality.

This alleges the importance of pedagogical action in order to bring discussions of EE to the school environment, such as the guidelines for sustainable development and GC, since such action can act as an alternative to assist in the construction of a society with critical thinking, problematizing and committed to the maintenance of ecosystems (Farias, 2021; Sousa et al., 2020). In this context, the exposure of the results of the VSQ evidenced the relevance of this proposal for the complementation of the training, in a significant way, of the research participants.

Based on the results from the VSQ, the second moment of application of the research was followed, which was the development of a sustainable experimentation called "Batch Adsorption Process through activated charcoal from the endocarp of the coconut". The mentioned activity was carried out with the students, in order to contextualize SDG 6 and GC. In view of this, there was a brief explanation and discussion with students about the social, economic and environmental issues involved in the SDG 6 guidelines and about the importance of green processes integrated with water treatment techniques.

At this juncture, an initial unanimous aspect was verified among the members of the class, which was a low affinity with Chemistry, since all students claim not to like or understand the discipline. Thus, it is possible to analyze once again how decontextualization in Science Teaching results in students' disinterest in studies (Roza Silva, et al., 2020). Based on this, the alternative of experimentation was presented at the Physicochemical Laboratory of IFPB, to attract attention and regain students' curiosity about the chemical contents, paying attention to their sustainable bias.

The planning of experimental classes had the purpose of discussing in a practical way, an alternative that met some principles of GC and fulfilled certain goals involved in SDG 6. Thus, there were debates regarding the management, distribution, treatment and quality of water. At this moment, it was also discussed about a Physical-Chemical phenomenon: the Batch Adsorption process for water treatment. The batch system was chosen, as it involves an experimental procedure that is easy to perform, functioning as an efficient alternative for application in practical classes in High School (Santos, 2021).

In this course, a script was made available to the research participants that detailed the steps of the first experimental class and then the activity began. The procedure aimed to remove the hardness of the water resulting from the presence of calcium ions ($^{Ca^{2+}}$) and magnesium ($^{Mg^{2+}}$) in the analyzed sample. As already informed, for the expansion of the described activity, a biodegradable adsorbent material was used: activated carbon from the endocarp of the coconut. The management of this natural resource guaranteed the experiment a sustainable and economic character, functioning as a viable option for the maintenance and cleaning of water.

It is important to emphasize that all actions included in the continuation of the experimentation were carried out by the students, under the mediation of the researchers. Therefore, the first performance of the students was the weighing of approximately 0.1000 grams (g) of the adsorbent material, and the measurement of the volume of 50 milliliters (mL) of a hard water sample. This mass of activated carbon was added to the sample in a 250 mL Erlenmeyer flask, which was kept in a water bath under agitation of 150 revolutions per minute (rpm), with a constant temperature of 35º C, for a time of 15 minutes. Figure 1 shows some records of these conducts.

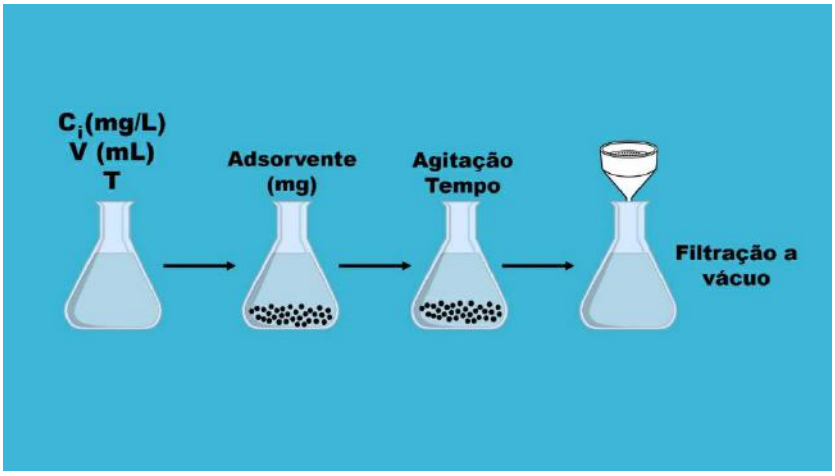
Figure 1 - Experimental batch adsorption procedure.

Source: Own source (2022).

As showed above, this active participation of the students during the laboratory experiment was essential for the verification of the research, because this active behavior signalized a greater interest for the progress of the activity and its steps for experimental procedure. This qualitative result indicates a great value for encouraging students in the environment school, promoting a more meaningful learning.

Following the information assigned in the experimental script, with the passage of the adsorption period, the biodegradable adsorbent material was separated from the hard water sample, using the vacuum filtration process with blue stripe filter paper. Accordingly, the adsorption scheme followed the steps illustrated in Figure 2.

Figure 2 - Schematic of the Batch Adsorption process.



Source: Own source (2022).

After the filtration was completed, the water sample was sent for analysis of the determination of the total hardness through a second experimental test. From this, the second experimental class was started: The determination of the total hardness of the sample. The hardness conferred to water is due to the presence of alkaline earth salts (calcium, magnesium, among others) and some metals, to a lesser extent (Moreira & Wiecheteck, 2018).

The method used in this step was complexometric titration with EDTA. This titration is based on the fact that ethylenediaminetetraacetic acid ($C_{10}H_{16}N_2O_8$) is an acid that acts as a hexadentate ligand, i.e. it can complex the metal ion through six coordinating positions. The EDTA titration method was performed because it is fast, practical and, with some modifications, applies to any type of sample (Tussolini, 2018).

In this order, students captured and transferred 100mL of the sample to other containers, and added 1mL of a buffer solution (ammonium chloride - ammonium hydroxide) to obtain a pH 10. After checking the pH with a universal indicator paper, an eriochrome-T black indicator was added to the solution. Subsequently, the students slowly and with constant agitation performed titrations in the sample using EDTA-Na at 0.01mol/L.

In the informed stage, the participants of the activity analyzed the change of color from red wine to blue, and noted the volume spent. The same procedure was done with a blank test of equal volume of distilled water, to facilitate the observation of the turning. Figure 3 shows some of the records of the execution of the steps mentioned by the students.

Figure 3 - Records of the experimental procedure to determine the Total Hardness.

Source: Own source (2022).

In this experiment stage, we analyzed an efficient turning point, since obtaining the blue color was verified in the sample after titration of the solution with EDTA, as shown in Figure 3. To verify the adsorbed amount of the parameter under study, the results of the hardness analyses in the water sample before and after the Batch Adsorption were compared. It is worth noting that for the application in High School, the calculations were designed and adapted in partnership with the class teacher, for a better understanding of the students. The first calculation is given by the expression of the result of the Batch Adsorption of the Total Hardness (1).

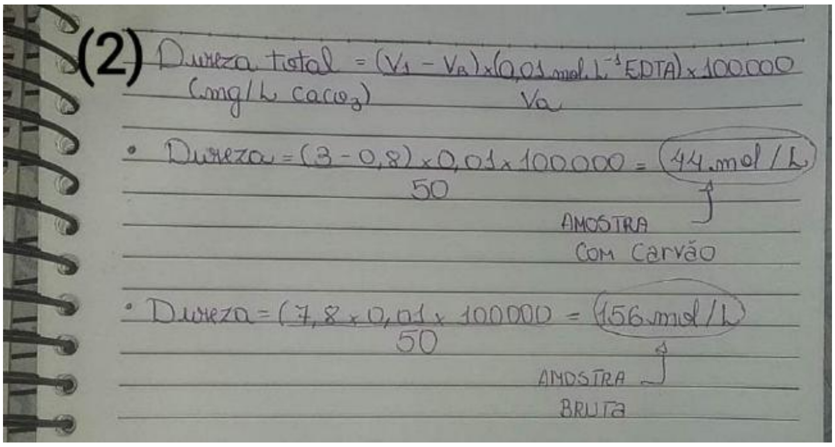
(1) Amount *Adsorbed* = *Hardness* *(before)* **- *Hardness*** *(after).*

Before performing the calculations of expression (1), students had to obtain the result of the total hardness before and after adsorption, in due order. For this, it was necessary to use a second mathematical expression (2).

$$\textbf{(2)}\ \boldsymbol{Dureza\ total}\ \left(\frac{mg}{L}\, CaCO_3\right) = \frac{(V_1 - V_b) \times (0{,}01\ mol\,.L^{-1}\ EDTA) \times 100.000}{V_a}$$

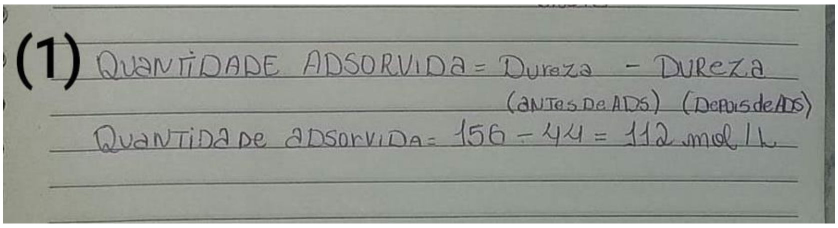
In expression (2), V_1 corresponded to the volume (mL) of EDTA-Na solution, spent on sample titration. The V_b was the volume (mL) of EDTA-Na solution, spent on the titration of the blank test. And finally theVa can be understood as the volume (mL) of the water sample. Thus, through the collaboration of the class teacher and researchers, the students performed the mathematical calculations (2) and (1), respectively, and obtained the quantitative results expressed in Figures 4 and 5.

Figure 4 - Expression Results (2).



Source: Own source (2022).

Figure 5 - Expression Results (1).

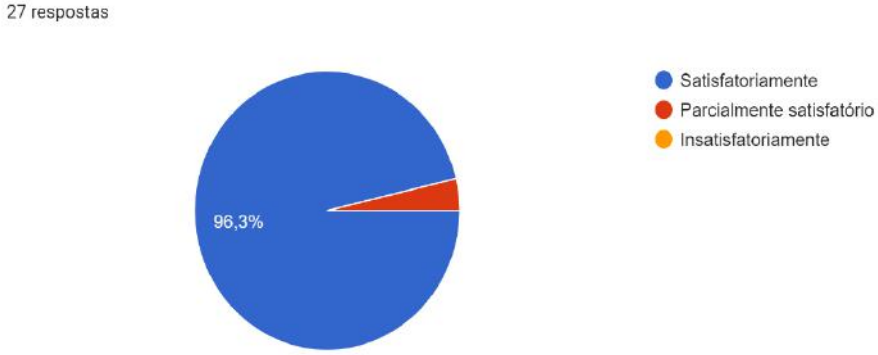


Source: Own source (2022).

Accordingly, according to the exposed data, 112 mol/L of the analyzed sample was adsorbed. This result demonstrates that batch adsorption worked as a viable technique for water treatment, in addition to being an efficient alternative for contextualizing the chemical contents involved and their socio-environmental dimensions, considering that the study of Adsorption, in Chemistry, is a useful phenomenon for several applications (Gasper & Pitol-Filho, 2019).

With the completion of the experimental classes, the last moment of application was started, referring to the FVQ. The evaluative instrument consisted of 2 (two) questions related to the development of the research. The first question was: **"***On a satisfaction scale, how do you evaluate that the project helped to learn about the content of Green Chemistry and the sixth objective of Sustainable Development (Drinking Water and Sanitation)?".* Graph 1 shows the students' answers.

Graph 1 - Answers to the first question of the FVQ.



Source: Own source (2022).

Compared to the results of the VSQ, the FVQ demonstrated the approximation of the students to the contents mentioned above, as they were able to associate the sustainable character of the classes. This is seen in Graph 01, and most of the class considered that all the activities proposed and developed in the research met satisfactorily for the learning of the target audience, in what gives to the Chemistry Teaching.

The second question of the FVQ indicated the following: "*Do you consider that the experimental practice carried out in the laboratory was characterized as a sustainable process? Justify your answer.* Thus, the students presented their considerations regarding the performance of the activity. The main comments were gathered in Table 2.

Table 2 - Answers to the second question of the FVQ.

STUDENT	COMMENTS
A	*Yes, because the batch experiments are simple, so they do not harm the environment, and the adsorption process through the activated carbon of the endocarp of the coconut is a biodegradable and natural alternative material, thus contributing to the sustainable environment.*
B	*Yes, because green chemistry seeks to act in line with the environment, that is, without causing its degradation or contamination. Thus, the experimental practice performed in the laboratory can be characterized as a sustainable process, because during the technique the endocarp of coconut was used, a biodegradable material, which does not cause impacts on the environment.*
C	*Yes, since there is a decrease in waste when compared to traditional techniques.*
D	*Yes. Because biodegradable and sustainable materials have been used in practice.*
E	*Yes, because we use activated carbon, a cheap and sustainable adsorbent.*

Source: Own source (2022).

With the analysis of the contributions of the students, it is noticeable the acquisition of the ability to identify the principles of GC and SDG 6 integrated with the technique of low cost for the treatment of hard water. Thus, the importance of the collaborative work of the pedagogical team is understood, since the initial objectives of the project were effectively achieved.

In this perspective, through the contextualization involved in the experimental classes, students, as well as teachers, acquired new complementary and essential knowledge for their academic backgrounds and for their lives in society. In addition, the effective participation and interest of these students in the course of practical classes was verified, a factor contrary to the initial comment of the students on the lack of affinity for the discipline of Chemistry. This result demonstrates the efficiency of using diversified methodologies.

As Oliveira et al. (2020) inform, teaching must have a significant value to attract student attention. Therefore, in view of the results presented, this pedagogical intervention was validated, as it was possible to verify how contextualization and experimentation can serve as motivating tools for an active education (Gonçalves & Goi, 2020). Thus, making students protagonists of the learning process.

4. Conclusion

Given the above results, the use of activated carbon from the endocarp of coconut as a useful and sustainable adsorbent material is a possibility in Chemistry Teaching from an environmental perspective. These conditions expose how natural and biodegradable resources also have potential related to water treatment, being characterized as a viable substitute for adsorbents that have the same effect, but are permanent in nature.

It was also analyzed how the batch adsorption process can serve as an efficient mechanism for cleaning water, as demonstrated by the data in the article. As this is a technique that also applies to meeting economic and social demands, it is a low-cost process that can be performed in regions that suffer from the shortage of drinking water.

In addition, this research indicates the importance of adopting pedagogical interventions that seek to change the traditional educational scenario. Such verifications were products of the project, before the activities the students showed little interest in the discipline and, after the applications, they started to express curiosity and protagonism in the development of the experimental procedures.

The present study demonstrated, through the evaluative questionnaires, a relevant change of perspective regarding the students' understanding. Since these students were unaware of the socio-scientific dimensions of Chemistry, even participating in a course with environmental core, and with the completion of the project, they were able to identify the presence of the principles of GC and the sustainable notions of SDG 6 involved in chemical content. Therefore, it is possible to observe the need for a foundation in EE to promote meaningful learning, since paradigms and socio-environmental issues are part of the daily lives of all students.

Thus, the investigative proposal contributed to the professional enrichment of researchers, given that through it the initial objectives present in the idealization of the project were met. Thus, the present research aims to enable the pedagogical community to acquire new skills and abilities regarding the work of the implementation of EE in the school menu, aiming future applications that integrate the development of Chemistry experiments teaching with its socio and environmental dimensions.

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